Studies of Four Glaciers in Greenland

By Børge Fristrup

Abstract

Four Greenland glaciers are investigated, their morphology are studied in relation to physiography, climate and change of climate. A relation is found between the rate of retreat and the temperature of the ice. With exception of the Ice Cap most af the Greenland glaciers are temperate glaciers (in South Greenland) or subpolar glaciers (even in North Greenland), the occurrence of superimposed ice is of importance for the ice accumulation.

Glaciological investigations were carried out in Greenland 1956-58 as a Danish contribution to the International Geophysical Year. The expeditions were sent out from the *Geographical Institute* at the *University of Copenhagen* under the direction of professor *Niels Nielsen*, Ph. D. and the writer, who also supervised all the operations in Greenland. The work was sponsored by the *Rask-Ørsted Foundation* and the *Carlsberg Foundation*, and various kinds of support were also given by the *Ministry of Greenland*. In a tragic accident on the Hurlbut Gletscher, where two men were killed, valuable help and rescue operations were given by the *American Rescue Squadron* from Thule Airbase.

Having regard to the great geographical variation of the Greenland glaciers, especially in respect of the climatology and physiography of the different regions in Greenland, the main programme of the investigations was to study glacier types in relation to geomorphology and the ratio of accumulation/ablation in relation to climate and microclimate. The glacier fronts were mapped in order to observe the oscillations in relation to climatic changes, and marked fix points were established for the purpose of resurveying in future years.

Four special selected glaciers were carefully investigated as representatives for particular geographical provinces, all being local

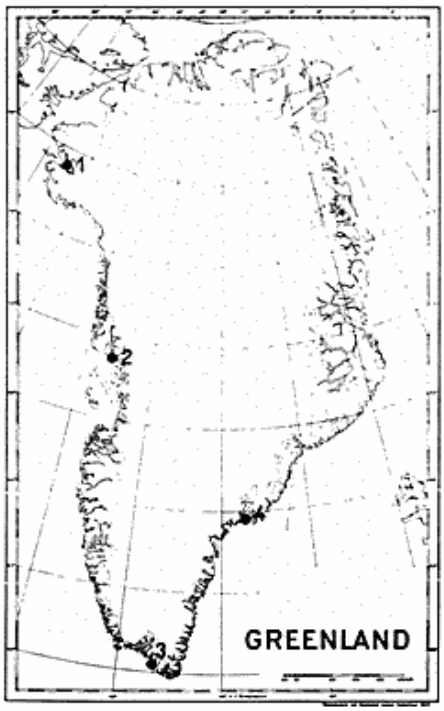

Fig. 1. Locations of the four glaciers: 1, Hurlbut Gletscher. 2, Sermikavsak. 3, Napassorssuaq Gletscher. 4, Mitdluagkat Gletscher.

glaciers outside the Greenland Ice Cap, and all of medium or small size, et being presumed that small glaciers will react more sensitively to less pronounced changes of climate. In selecting the glaciers several desiderata were of importance. All the expeditions were small of 4-6 men, requiring the establishing of no more than one station in each province, and for the same reason the glacier should not be too large or of too complex a form, and when possible the glaciers should not reach the sea, as calculations of production of icebergs had to be avoided. The glacier should be typical for the province, regarding size, type, exposure to prevailing wind direction and the sun and so on. Transport problem in establishing the base camps made it necessary to select glaciers not too far away from the sea. At three of the stations the whole equipment was brought to the shore by ship, while the station at Hurlbut Gletscher was established by sledging with dog teams. All the glaciers were carefully selected with regard of safety, several of the expedition members having had no previous experience of glaciers in Greenland, and real mountaineering should be avoided.

The location and size of the glaciers is given in table 1 and in fig. 1.

Description and morphology of the glaciers

Napassorssuaq Gletscher is situated on Sermersôq Ø, the largest and westernmost of three islands in the entrance to the Sermilik fjord in Nanortalik region; the island is therefore part of the South Greenland granite region with rather high and very steep mountains. The glacier occupies the southern part of a 6 km. long valley, a typical glacier eroded hanging tributary valley 400 m. above sea level and from there ascending to a threshold 1000 m. above the sea. The valley system, which also can be followed to the north on the mainland, is of tectonic origin and afterwards glacier eroded. The glacier itself

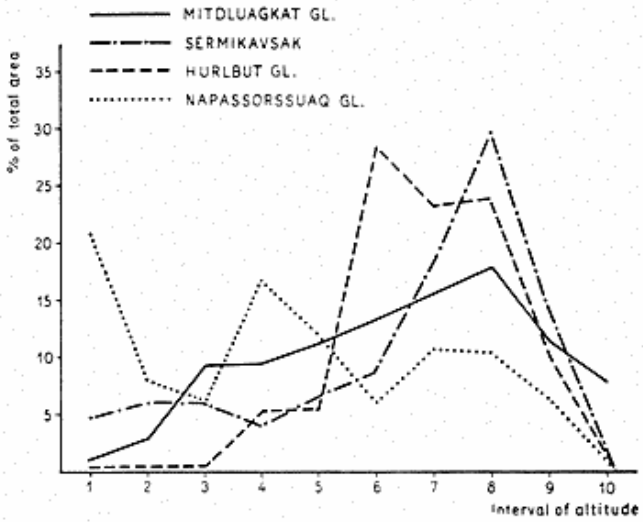

Fig. 2. Curves of frequencies ot different height intervals for the four investigated glaciers.

is 3 km. long and 500-900 m. wide, its front terminates in a small lake 495 m. above sea level with a nearly vertical ice cliff, 12-15 m. high; along both lateral parts of the front extensive areas of dead ice were found. No part of the glacier front is afloat, as the lake is shallow. The glacier descends in three or four ice falls, most probably related to differences in the resistance of the substratum, as the glacier is rather thin according to observations of the topography of the region.

The glacier is rather small, which is typical of many of the valley glaciers in the region. According to the classifications proposed by *Ahlmann* (1948) a calculation of the different height intervals was made, the curve is shown on fig. 2. From the general impression gained it is quite evident, that Napassorssuaq Gletscher is a typical valley glacier of a type that is common in that part of Greenland. A study of the curve shows however that the frequencies of the different height intervals do not coincide well with the classification as a valley glacier, the curve represents a transition between valley glacier IV and a piedmont glacier. The explanation of this is that the lower marginal part of the glacier at present is dead ice and is merely a relict of the former greater extension of the active glacier, but still morphologically a part of the glacier. The type described here is very common in Greenland and therefore ought to be called the Greenland valley glacier type as a fifth of the Ahlmann valley glacier types.

The glacier was explored in 1957 by a group of five with *Jens*

Table 1.

Coordinates of base camp	Area	Glacier type
Hurlbut Gletscher..... lat. 77°23'30"N — long. 67°57'W	188,0 km²	Glacier cap
Sermikavsak..... lat. 71°11' N — long. 53°03'W	21,6 km²	Valley glacier
Napassorssuaq Gletscher..... lat. 60°18' N — long. 45°13'W	2,1 km²	Valley glacier
Mitdluagkat Gletscher..... lat 65°40'40"N — long. 37°54'W	36,4 km²	Transection glacier

Fabricius as party leader. Glacial meteorological investigations were carried out and surveying of the glacier front. Lateral moraines were not well developed, and there was no terminal moraine as the glacier terminates in the lake. The glacier is rather heavily crevassed with both transversal and longitudinal crevasses.

From a visit by *J. A. D. Jensen* in 1894 a series of photographs shows us the position of the front at that time. Since then the glacier front had retreated 200 m. to 1951 and the retreat has continued so that in 1957 the glacier front has receded 350 m.

Sermikavsak (meaning the paltry glacier) is situated on the western side of Upernivik Ø and was selected as a representative of the great West Greenland region, comprising the area from south of Disko Bugt to the southern part of Melville Bugt. The region contains several well defined glacier types such as the typical cirque glaciers in the basalt region on Disko and Nûgssuaq and the typical valley glaciers in the highly glacierized region between Nûgssuaq and Svartenhuk peninsula. The climate is arctic with cold winters, rather short summers and rather much precipitation. Further investigations will subdivide the region. Sermikavsak is the southern one of the four glaciers descending to Igdlorssuit Sund from the central high mountainous region of the island. The glacier terminates nearly a thousand metres behind the coastline leaving space for outwash plains and terminal moraines. Old moraine systems can also be followed on the sea bottom in front of the glacier valley. The firn area of the glacier is very well defined nearly 1000 m. above sea level, and from there the glacier descends in a tongue 15 km. long and 1 km. wide. Thus the glacier itself completely occupies the upper part of the troughshaped valley and is surrounded by the 2000 m. high

mountain chains, the mountains being very steep, and collects much snow during the winter, the result being that numerous avalanches drop down on to the glacier. Sermikavsak therefore receives more snow than it should according to the average snowfall on the region. The glacier thus being partly nourished by avalanches, this is a very characteristic feature of many glaciers in the Umanak Bugt region. In most other parts of Greenland avalanches are somewhat rare, and normally they do not occur in northern Greenland, where the climate is too arid and the snow too powdery and fine grained. Some of the glaciers round Kangerdlugssuaq and Kangerdluarssuk fjords seem to be nearly vertical, and the snow on the ice therefore will move down like an avalanche and come to rest at the snout, making a very large terminal snout frequently in the form of a steeply rising cone. At some of the glaciers the central nearly vertical part of the glacier tongue now, owing to the amelioration of the climate, has melted away so that the glacier is divided into a higher part with the firn area and a glacier tongue descending down the mountain side, and below that an independent cone built up of snow and ice coming down with the avalanches from the upper part. This type is rather frequent here and most probably it will only be so well developed in high latitudes with a low sun and very steep mountains.

Sermikavsak is a typical valley glacier II of Ahlmann, and a characteristic feature is the well developed ice falls.

Investigations there were carried out in 1956, 1957 with *J. Tyge Møller* as group leader. A description of the surveying has been published by *Møller* (1959a) as well as a study of the periglacial landscape in front of the glacier (1959b). Studies of the weather have been published by *Hans Kuhlman* (1959) and according to him, the weather could be divided into four different types, the most dominant was radiation weather (61% of all observations), overcast weather was found in 17,7% and foehn weather in 6,9%. Special investigations were carried out concerning the temperature and wind profiles above the ice. Gravity wind (katabatic wind) was found in 78% of the observations, and round 80% of the ablations was found to be due to radiation.

As by the other glaciers studies of the front oscillations were made. From 1934 to 1953 the front had retreated 600-700 m. and from 1953 to 1957 the retreat was 150 m. giving an annual withdrawal of 34-38 m.

Hurlbut Gletscher is a glacier cap, which is the dominant type in

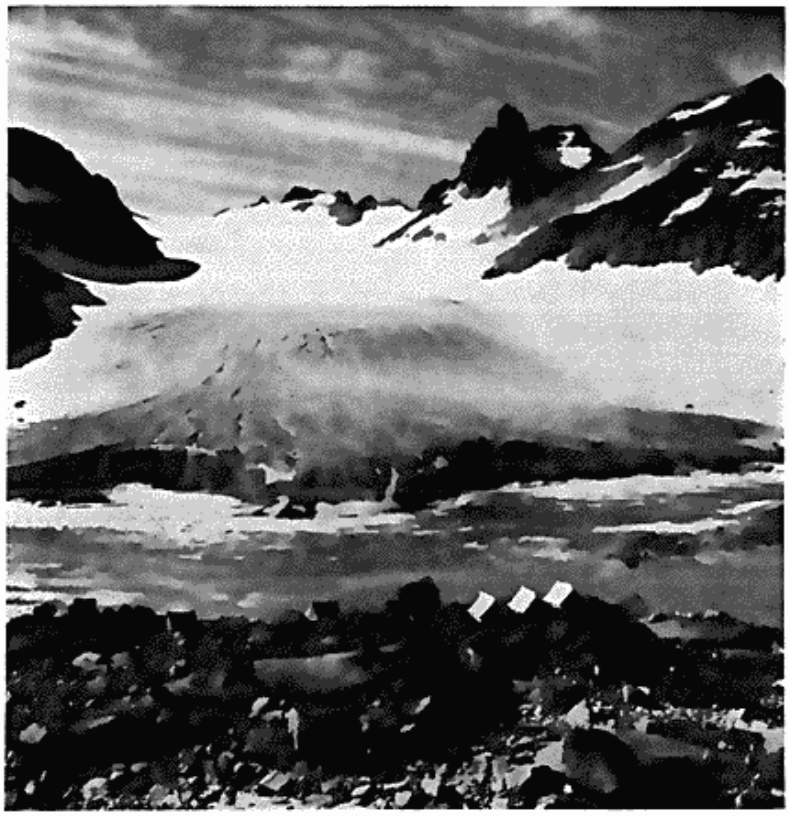

Fig. 3. The Napassorssuaq Gletscher photographed from the site for the meteorological observations, the base camp is situated near the lake in front of the glacier. Phot. B. Fristrup.

North Greenland, the region being part of the rather monotonous sandstone plateau belonging to the Thule formation. Typical valley glaciers therefore are rare, the only exceptions being Kap York peninsula and round the outer section of J. P. Koch Fjord. The climate is high arctic with severe winters and insignificant precipitation and with very small diurnal temperature variations.

The glacier covers the highest and central part of a plateau between Inglefield Bredning and Olrik Fjord. As seen from the diagram fig. 2 the total area of glacier tongues is very little, and at the present time only one of the tongues really reaches down to the sea at Inglefield Bredning, the front stands on the beach and is above sea at low tide, by high tide there is a small production of ice pieces. Towards Olrik Fjord there are two broader but rather short glacier lobes, which do not reach below 300 m. above sea level. Meltwater canyons have been formed in the ice, indicating that at least some part of the glacier at present is stagnant ice. The total thickness of the glacier cap is less than 400 m., and the drillings with core

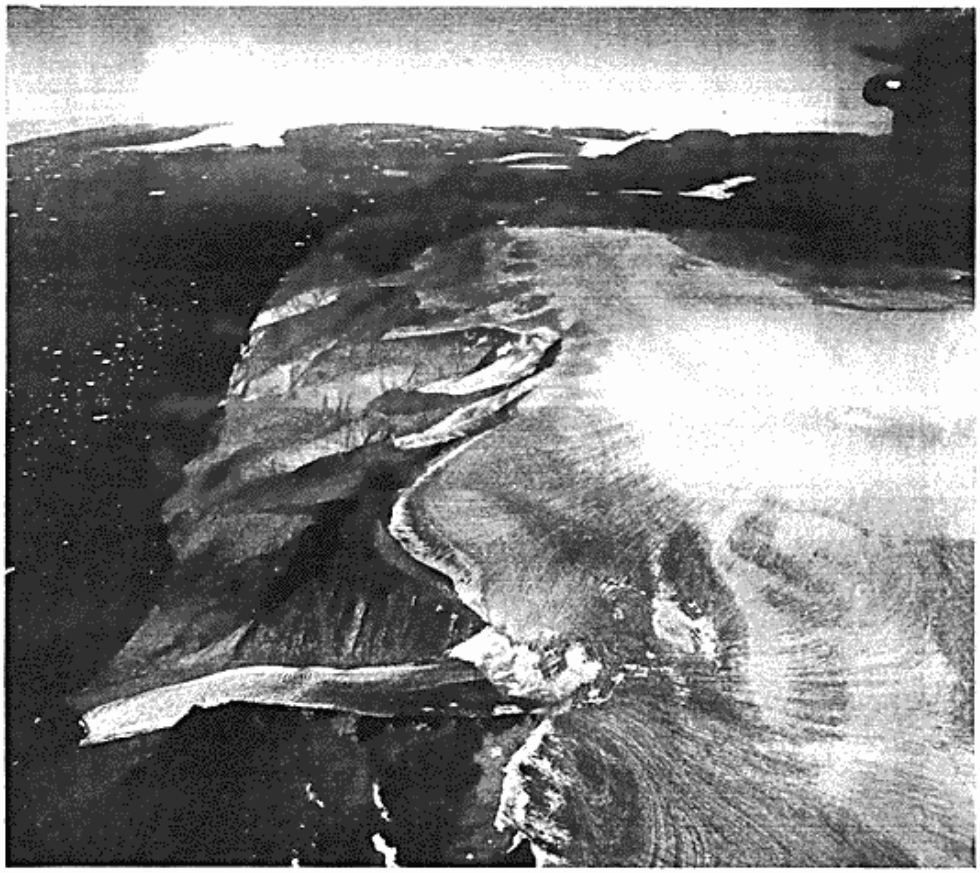

Fig. 4. Aerial view of Hurlbut Gletscher. To the left Inglefield Bredning. The glacier in the backgrund is the Heilprin Gletscher descending from the Ice Cap.

samples reveal superimposed ice to at least 15 m. (the deepest core drilling). The firn area is very insignificant, and in some years there will be melting all over the glacier, so that the glacier may be nourished in same way as described by *P. D. Baird* (1952) for Barnes Ice Cap on Baffin Island, e.g. by the refreezing of meltwater and water-percolated snow and ice. Along the edge of the glacier cap proper the ice is very thin, and as is characteristic of many of the glacier caps and highland glaciers in North Greenland there is no terminal moraine along the ice on the plateau; the glacier seems unable to pick material up from the substratum. Cryoconite holes are frequent. Along the glacier tongues are lateral moraines, those moraines on the glacier tongue descending towards Inglefield Bredning being well developed, the blocks are sharp-edged and must have been transported on the surface and not in the ice, the material must have come down with landslides from the mountain sides.

At the present time the glacier has withdrawn and the lateral

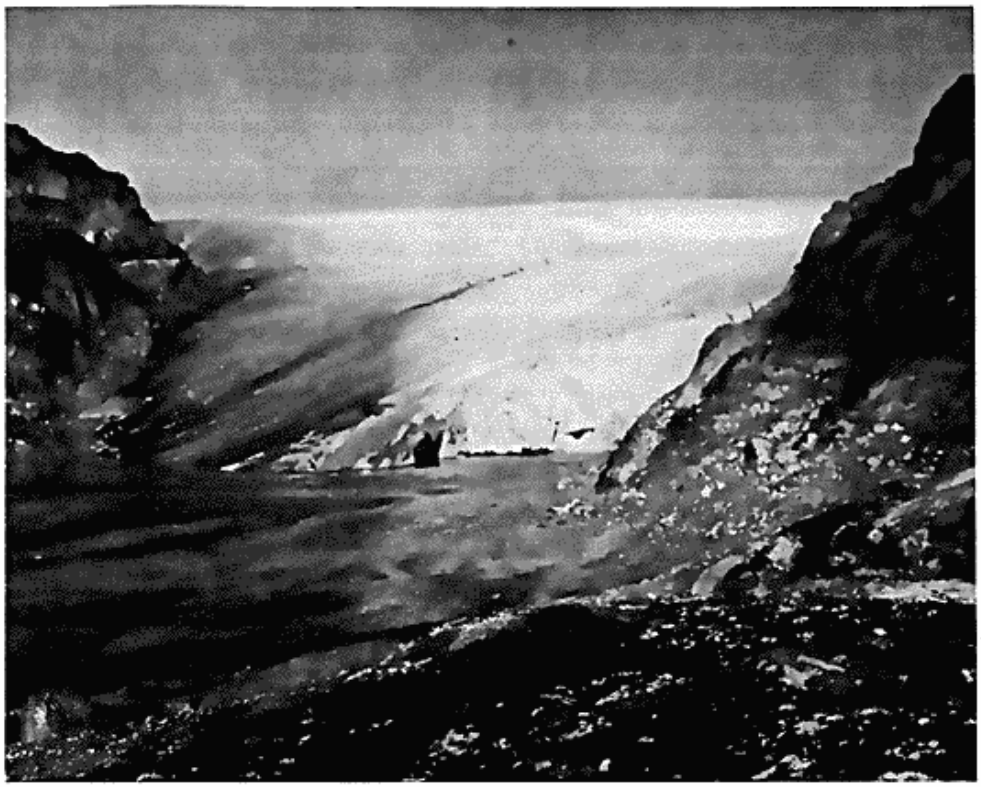

Fig. 5. The front of Mitdluagkat Gletscher photographed by K. Milthers in 1933.

moraines are longer than the glacier itself. The moraines most probably are very old, and remains of very old moraine systems were found; the sheltered sand beach, which was used for base camp, in reality is situated between two old moraines. Because of solifluction the old moraines are very low and only to be followed by counting very characteristic blocks such as a white quartzite. The studies indicate not only that the glacier at a previous time was longer, but that it was of another form, the lower part was broader of a typical piedmont or tongued form with the ice from a rather narrow valley part spreading radially out to the sides. This is typical of many glaciers in North Greenland, and good examples can be found at several places, this glacier form most probably was dominant previous in North Greenland, and most of the present glaciers of that form may be regarded as relicts of another climate. The glacier retreat is very insignificant, most probably less than 5 m. per year, and according to photos taken by Dr. *Gilberg* in 1939 the glacier snout now is more narrow than before.

Mitdluagkat Gletscher is one of the biggest glaciers on Angmagssalik Ø and has been found representative of the East Greenland

Fig. 6. Mitdluagkat Gletscher photographed from the same point in 1958. Phot. B. Fristrup.

humide climate with a rather heavy snowfall and temperature conditions greatly influenced by the drift ice. The glacier surrounds the 973 m. mountain Mitdluagkat, which in reality is a nunatak in the glacier. Along the eastern and southern sides the glacier is surrounded by mountain chains culminating in the very steep Vegas Fjeld, 1084 m. The western and the northern edges of the glacier are open, and the glacier is drained towards west, i. e. towards Sermilik fjord. One glacier tongue descends to a flat-bottomed valley and about a fourth of the discharge from the glacier area runs here through. The tongue is rather broad and the front is only 4,1 m. above sea level. Mitdluagkat is a transection glacier according to Ahlmann's definition.

Mitdluagkat Gletcher was studied in 1958 and the normal routine investigations were carried out, such as surveying the fronts, glacial-meteorological investigations, ablation measurement and so on. The period of observations was shorter here than at the other glaciers according to the ice difficulties in the fjord. Beside the normal studies a special investigation was made of the runoff

from the glacier, the results have been published by *Larsen* (1959), the diurnal variation of the discharge was very typical with maximum at 17.00-18.00 hrs., and the discharge varied between 2 and 4 cbm./sec. In connection with the runoff studies investigations were also made on some of the ice-dammed lakes. Along the southern, western and northern edges of the glacier were several ice-dammed lakes, and their morphology was studied; in September the river gauge showed a series of tappings from some of the lakes. A special search therefore was established, and two lakes were found to be drained out. The total tapping of one of the lakes has been calculated at between 400.000 and 450.000 cbm. The water drained through or under the ice and a great increase of the water level was found in the river from the glacier tongue. The water from the drained-off lakes appeared not in the glacier port at the front, but far up on the lateral drainage channel, and from there followed the glacier margin down to the river; the water was easy to recognize because of the colour from the suspended material. One of the lakes was tapped through a tunnel at the ice. The lake was so completely drained out, that it was possible to get into the drainage channel and follow the tunnel for a couple of hundred metres. This glacier tunnel was rather big, 5-10 m. high, and 10-30 m. wide, and near the entrance the room in the ice was even bigger forming a large cavern. The water had been drained through this tunnel with great force, many ice-blocks from the collapsed glacier front having been carried by the water stream and now filled the tunnel, at many places is was therefore difficult to find a way through, and in the end we had to give up. The floor of the ice tunnel was ice, covered only by a thin layer of mud and clay; at some places there were narrow crevasses down to a deeper level. The roof of the tunnel was vaulted at the entrance near the glacier port. Here and there the tunnel was divided into different rooms by ice columns formed by water erosion, and supporting the roof. It is most likely that bigger ice tunnels may be found in the ice behind some of the other lakes. The collapse of such ice caverns may give rise to calderons, such were found at several places. The cause for the lake tapping has been discussed by *Larsen*, who also found a very interesting accordance with the discharge curves from the great »jökull-hlaup« from Iceland; characteristic is a rather gentle increase of the discharge to maximum value and then coming to a sudden drop. An observation from a flight over the glacier in late August 1959 shows the ice-dammed lake as re-established, therefore it seems most probable that the

Fig. 7a. The upper part of Sermikavsak seen from the western mountain side. Phot. J. T. Møller.

Fig. 7b. The lower part of Sermikavsak with the glacier front seen from the western mountain side. Phot. J. T. Møller.

tapping was caused by a hydrostatic lifting of the ice near the lake, in connection with a great rainfall and high water level in the lakes.

The Mitdluagkat nunatak is an old nunatak, which has been ice free for a long time. The firn area of the glacier is insignificant, and superimposed ice is very important. By a visit in 1933 *K. Milthers* took some phototheodolite exposures, and our photos show a retreat of considerable dimensions; the total withdrawal in 25 years is about 400-500 m., and very impressing is the formation of new nunataks, which now divide the glacier tongue in two lobes emerging below the nunatak, and a new nunatak south of the present one is under development. The new nunatak had no vegetation and the stones and blocks were quite unstable, not having yet found their final position. A number of stone counts were established, and no relations between the longitudinal axes and the former movement direction of the ice were found, the longitudinal axis were only related to the gradient of the terrain and the direction of the solifluction. The nunatak is proof of a lowering of the ice surface of more than 50 m. and the average withdrawal per year of the glacier front is 16-20 m. A retreat of the same order of magnitude was found at several other glaciers visited in the district.

Glacier morphology related to ice temperature

By the investigations we found a greater retreat of the glaciers in South Greenland than in North Greenland. In drilling holes thermo-electric measurements were taken at regular intervals during the summer, some few readings were taken also in winter on the Hurlbut Gletscher. Some of the results will be evident from fig. 8 and 9; it will be seen that the yearly temperature variations continue down to 10-12 m. below which the temperature is nearly constant, and even in September the cold from the previous winter is still present, as ice is a very poor heat conductor. There is a good correlation between the ice temperature and altitude above sea level. From fig. 8 it will be seen that there is a great geographical variation of the temperatures in the ice. Two glaciers: Napassorssuaq and Mitdluagkat have temperatures very nearly the melting point in August, the temperature vary between zero and — 1° at least down to 15 m. The Hurlbut Gletscher is a cold glacier with temperature of — 16° at 15 m. depths. While the Sermikavsak seems to be a transition form; this is in good accordance with the difference in geographical latitude, a similar relation between temperature and geographical

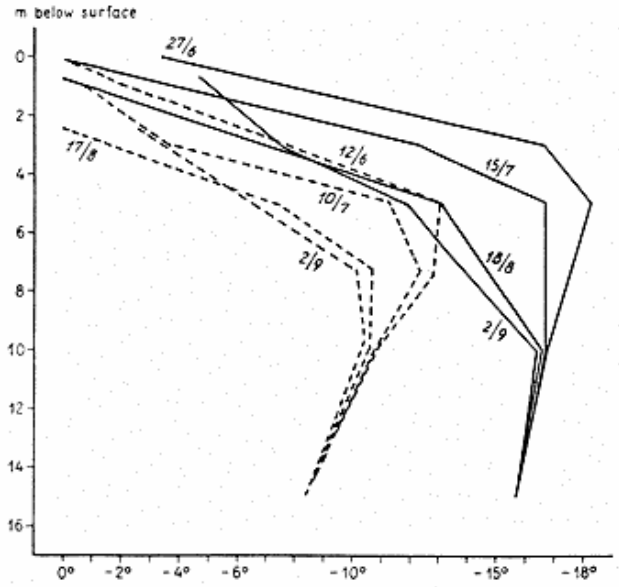

Fig. 8.

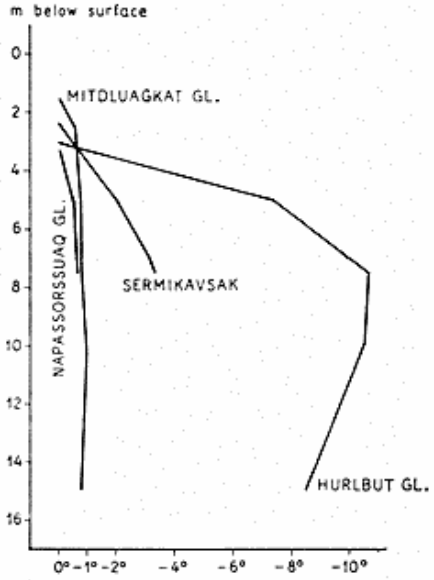

Fig. 9.

Fig. 8. Temperature in the ice in August in the four glaciers.

Fig. 9. The temperature variation during the summer time at two different stations on the Hurlbut Gletscher. The curve to the right is from the station on the Ice Cap near the highest point of the glacier, and the curve to the left is from the glacier tongue descending to the Inglefield Bredning.

latitude having been demonstrated by *Benson* (1959) for the Greenland Ice Cap.

According to Ahlmann's definition of glaciers related to temperature the Napassorssuaq and Mitdluagkat may be typical temperate glaciers belonging to the same type as the Scandinavian and the Iceland glaciers. According to morphological studies of other South Greenland glaciers it is possible to say, that most of the local glaciers in South Greenland belong to this type. The North Greenland glaciers are polar glaciers according to Ahlmann's definition, the Hurlbut Gletscher is a polar glacier, where a certain amount of melting takes place, and studies of the glaciers in Peary Land *(Fristrup* 1949, 1951) show that ice caps in that region also have a summer melting. Therefore only part of the Greenland Ice Cap and probably one or two of the largest glacier caps in North Greenland may be considered as high polar glaciers, all the rest may be subpolar glaciers, if not temperate glaciers; also the Sukkertoppen ice cap is a subpolar glacier.

As the yearly temperature variations only affect the upper 10-12 metres of the ice, it will be seen that the cold glaciers in North Greenland will react only very slowly to changes of climate as far as the temperature concerns. But they will of course be rather sensitive

to changes in precipitation. As shown by *Diamond* (1956, 1958) there was a slight decrease in annual amount of precipitation from 1920 to 1954 in North Greenland. The cold ice temperatures of the North Greenland glaciers may possibly be the explanation of the question why the northern glaciers in Greenland according to *Lauge Koch* (1928), *Fristrup* (1952) and others seem to have started the withdrawal of the fronts much later than the glaciers in South and Central Greenland. As will be seen from the above mentioned investigations the annual withdrawal is at present less for the North Greenland glaciers than in South Greenland.

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